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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 113

Contribution from the Bureau of Entomology, L. O. Howard, Chief

August 22, 1914.

(PROFESSIONAL PAPER.)

THE LESSER BUD-MOTH.

By E. W. Scott and J. H. Paine,

Entomological Assistants, Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the spring of 1912, while engaged in apple spraying experiments at Benton Harbor, Mich., the senior author noticed the work of a small larva in the buds of unsprayed apple trees. The injury inflicted by this minute insect was quite severe in a neglected orchard near the laboratory, and this insect, among others, was the most important factor in the destruction of the entire crop of fruit. From the character of the injury, the attack on the swelling buds, and the tying together of the growing leaves the damage was at once attributed to the eye-spotted bud-moth (*Tmetocera ocellana* Schiff.).

In 1913 a study was made of the life history and habits of this insect, supposedly the eye-spotted bud-moth, and experiments were tried with remedial measures. The first discrepancy noticed between the habits of this insect and those of the eye-spotted bud-moth, as stated in literature, was the fact that the hibernaculæ were not necessarily situated near the buds, but were to be found in any suitable place upon the limbs. Following this, many other even more striking differences in habits were noted during the course of the season, and the fact was soon impressed upon the writers that they had to deal with an insect whose economic importance had not been recorded in the United States.

The adult moths, upon submission to Mr. August Busck, of the Bureau of Entomology, were identified as *Recurvaria cratægella* Busck (1903),[1] a species described by him (with no indication of its life history) in 1903 from material submitted by Mr. William Dietz from Hazleton, Pa., who reared it from hawthorn (*Cratægus tomen-*

[1] Bibliographic citations in parenthesis refer to "Literature cited," pp. 15 and 16.

Note.—Describes an imported insect which is very destructive to several kinds of growing fruit and has attained quite wide distribution throughout the Northeastern and North Central States.

tosus) in June. Busck makes the following statement in his description:

I am, at present, unable to separate this species from a series of authentic European specimens of *R. nanella* Hübner, and I am conscious of the probability of my making a synonym of this species, the life history of which, according to Meyrick's Handbook of British Lepidoptera, is not definitely known, but which is variously said to feed in flowers or the shoots of pear or on lichens growing on the trunk.

However, in the same year Houghton (1903) published a short though complete account of the life history of *Recurvaria nanella*, corresponding in detail to our observations in Michigan. In view of this identity between the life histories as observed in Europe and America, Busck feels certain of the identity of the two insects, as appears in a statement by him in the accompanying footnote.[1]

HISTORY OF THE SPECIES IN EUROPE.

Stephens (1834) records *Recurvaria nanella* as "not very uncommon in gardens within the metropolitan district (London), frequenting the trunks of apple trees in June and the beginning of July."

Stainton (1854) records the larva as feeding in May, in England, on the pear, making a gallery across the flowers with pieces of the petals and stamens interwoven with silk.

Rössler (1871–72) observed the tying together of the young leaves of fruit trees by larvæ of *Recurvaria nanella* and its effect in hindering the development of the new leaves, at Wiesbaden, Prussia. The insect was present in such large numbers as to attract the attention of the public to the deformed trees and to arouse the fear that serious harm would result. In view of the fact that the larva was so small, ate so little, and did not attack the blossoms, Rössler considered that it was not to be feared.

Houghton (1903) published quite a complete though short account of the life history and habits of *Recurvaria nanella* from an economic point of view, as observed by him in England. His attention was directed to the insect in an apricot orchard, where the crop had been practically destroyed by it in previous years. He was the first to note the fact that the larva, after hatching, passes the time before hibernation as a miner in the leaf. He also observed that it was the habit of the larvæ to bore into the swelling buds in the spring. The larvæ appeared in swarms on peaches and apricots and less commonly on cherries and plums. In his description of the larva he men-

[1] *Recurvaria crataegella* Busck (Proc. U. S. Nat. Mus., v. 25, p. 811, 1903) is identical with the European *R. nanella* Hübner, as already suggested in the description. At that time the life history of the species was but fragmentarily known in Europe, and it was deemed the soundest course to give the American form a separate name, even though it was realized that it would probably prove the same as the European species. The subsequent careful study of the life history in Europe by J. T. Houghton and in this country removed all doubt about the synonymy.—A. B.

tions the different colors assumed by the caterpillars as they near maturity, and this observation corresponds with our own.

DISTRIBUTION OF THE SPECIES.

The distribution of *Recurvaria nanella* in Europe is given by Staudinger and Rebel (1901) as follows: Central Europe, Sweden, northern Spain, southern France, central and northern Italy, Dalmatia, and southwestern Russia.

Specimens of *Recurvaria nanella*, all identified by Busck, have been received by the Bureau of Entomology and by the United States National Museum from a number of localities in the United States. As previously stated, the first specimens were received in 1903 from Mr. William Dietz, Hazleton, Pa. Others have been received from Pittsburgh, Pa., collected by Henry Engle; from Denton, Md., collected by Quaintance in April, 1905, on peach; from College Park, Md., by Girault in August, 1905, on apple, "from fruit;" from Bennings, D. C., collected by Girault in May, 1905, "found resting in numbers on trunks and larger limbs, simply swarming on peach trees;" from Albany, N. Y., by Felt; from Hampton, N. H., by Shaw; from Dublin, N. H., by Busck; and from Cleveland, Ohio, by Prior, the larvæ eating apple leaves.

It is improbable that the insect has attained this distribution in the United States through natural means from a single importation from Europe, but it is likely that it has been imported a number of times on nursery stock shipped to various points in this country. In fact, the importation of this insect, which spends six or seven months in hibernation concealed in minute cracks and crevices of the bark, could occur most easily.

FOOD PLANTS.

In the earlier references to *Recurvaria nanella* the pear is usually given as the host plant. Houghton, however, failed to observe it infesting this fruit, but finds it swarming on the apricot, destroying the crop. On the other hand, it is certain from the observations of other authors that the pear is a favorite food plant, for the insect has often been observed frequenting pear trees in the vicinity of London. Other European host plants are apple, peach, plum, cherry, wild plum, and hawthorn. It has been recorded as attacking the peach in swarms. At Benton Harbor, Mich., the insect was reared from apple, peach, pear, plum, and sweet and sour cherries. The infestation was light on plum and cherry. At Hazleton, Pa., it was reared from a wild hawthorn.

It is interesting to note the immunity of the Kieffer pear to the attack of the young larva in the fall or leaf-mining stage. The larvæ, upon hatching, bore into the tissue of the leaves of this va-

riety, showing no discrimination against it; the mines, however, are never developed to any great extent, for the tissue of the leaf about the mine turns dark and apparently hardens, effectually stopping the operations of the insect. Many larvæ must thus meet their death, being unable to secure food. This is another instance illustrating the resistant qualities of the Kieffer variety of pear.

CHARACTER OF THE INJURY.

The first attack by the larvæ of *Recurvaria nanella* in the spring is aimed at the swelling buds (Pl. II, figs. 3 and 4) of both blossoms and leaf. The insect bores into the bud, eating the tender tissues as it goes, showing particular partiality for the young stamens and pistil, if it has been lucky enough to select a blossom bud. As the buds open and the leaves begin to expand the larva ties the tips of the leaves together, spinning about them a tiny silken thread, thus greatly deforming and hindering the succeeding leaves as they develop (Pl. I, fig. 2). It is this injury, when inflicted by countless numbers of this tiny caterpillar on nearly every bud on a tree (Pl. I, fig. 1), that results in a serious, if not almost total, loss of the crop.

SYNONYMY.

Recurvaria nanella.

Tinea nanella (Schiff.) Hübn., 1796 (?), Tineæ, pl. 39, fig. 267.
Euota pruniella Schiff., 1776, Syst. Verz. Schmet., C. 75.
Tinea aleella Fab., 1794, Ent. Syst., v. 3, pt. 2, p. 317.
Recurvaria nana Haw., 1829, Lep. Brit., v. 4, p. 554.
Trichotripis nanella Hübn., 1816, Verz. bek. Schmet., p. 425, No. 4143.
Anacampsis nana (Haw.) Curt., 1827, Brit. Ent., v. 4, pl. 189.
Anacampsis aleella (Fab.) Steph., 1829, Syst. Cat. Brit. Ins., pt. 2, p. 197.
Gelechia nanella (Hübn.) Her.-Schäf., 1853–1855, Syst. Bearb. Schmet., v. 5, No. 416.
Recurvaria nanella (Hübn.) Heinem., 1870, Die Schmet. Deutsch. u. d. Schweiz., Bd. 2, p. 280.
Aphanaula nanella (Hübn.) Meyrk., 1895, Handb. Brit. Lep., p. 580.
Recurvaria cratægella Busck, 1903, *in* Proc. U. S. Nat. Mus., v. 25, p. 811.

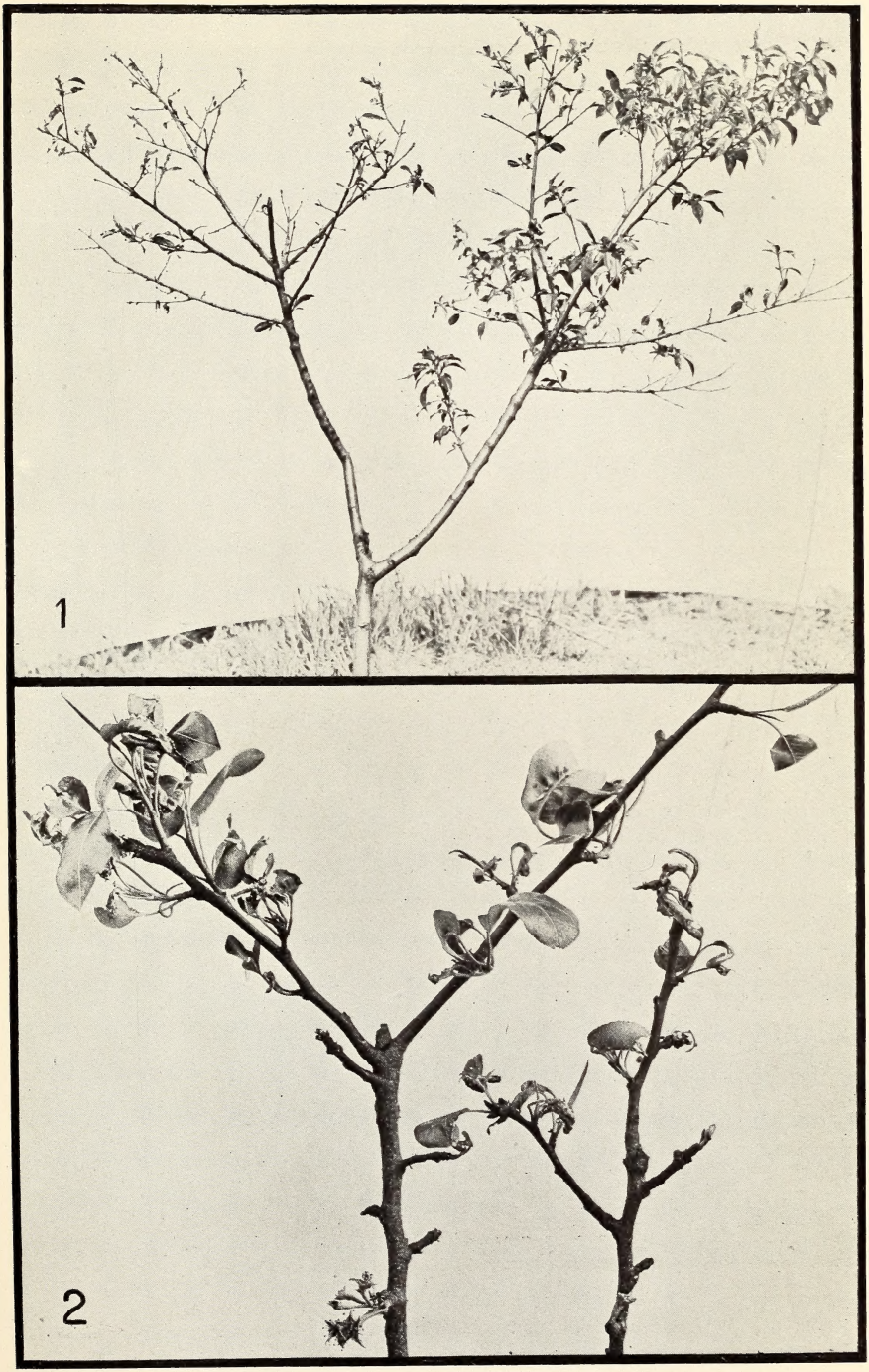
DESCRIPTION OF THE LESSER BUD-MOTH.

THE ADULT.

The adult (Pl. II, fig. 6) of *Recurvaria nanella*, or lesser bud-moth, is a very small streaked moth with a wing expanse of half an inch, although as it appears on the tree trunks it is not more than one-fourth of an inch long; the black and white banded legs are quite conspicuous. The following technical description is as given by Busck for *R. cratægella* (1903):

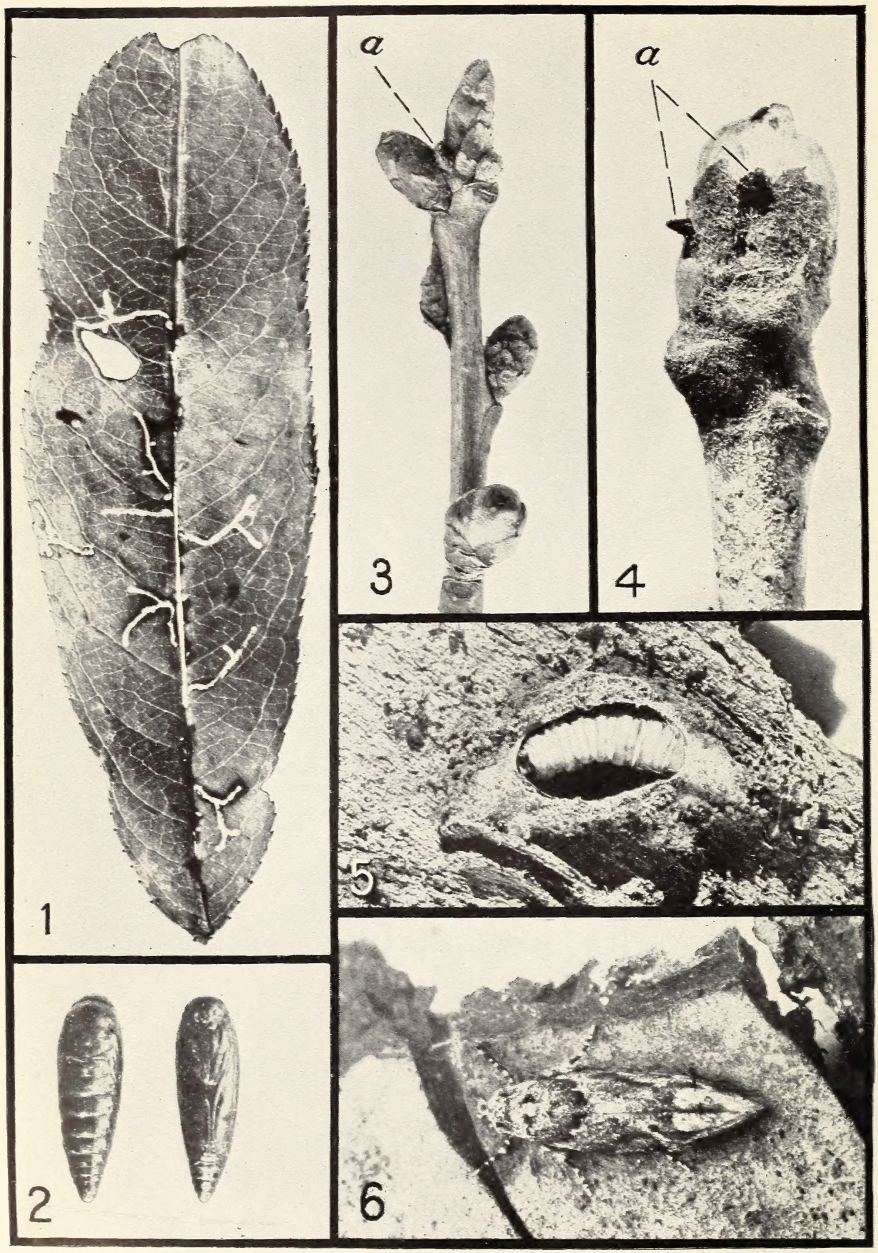
Antennæ whitish, with indistinct, narrow, dark-brown annulations. Labial palpi whitish, with two black annulations on each joint; tip white. Face, head, and thorax white, suffused with fuscous.

Fore wings white, thickly sprinkled with fuscous.. From near the base of the costa is an outwardly directed, oblique, ill-defined black streak, which



WORK OF LARVÆ OF THE LESSER BUD-MOTH (RECURVARIA NANELLA).

Fig. 1.—Neglected peach trees partially defoliated by larvæ. Fig. 2.—Work of larvæ on pear twigs resulting in the destruction of some of the buds. (Original.)



THE LESSER BUD-MOTH (RECURVARIA NANELLA).

Fig. 1.—Partially developed mines of larvæ in a peach leaf. Fig. 2.—Upper and lower views of pupa. Fig. 3.—Excrement (*a*) deposited at entrance to larval burrow in cherry bud. Fig. 4.—Apple bud infested with larvæ, showing excrement (*a*) deposited at entrance to burrows. Fig. 5.—Full-grown larva in cocoon on bark removed from trunk of pear tree. Fig. 6.—Moth at rest on bark. Fig. 1, slightly enlarged; figs. 2, 5, 6, about six times enlarged; fig. 4, about twice enlarged; fig. 3, natural size. (Original.)

does not reach the dorsal edge and which is more or less interrupted at the fold and bordered on the outside with white scales. From the middle of the costa is a similar, parallel, interrupted dark streak still less clearly defined. At the end of the cell in the middle of the wing is a short, black, longitudinal streak; below this on the dorsal edge is a small black spot, and on the costal edge are two similar black spots, one at the apical third, the other just before apex. Cilia white, speckled black, and fuscous. Hind wings light silvery fuscous; cilia a shade lighter than wing; male without costal hair pencil.

Abdomen dark fuscous, anal tuft silvery gray; legs white, with black annulations; hairs on posterior tibia silvery white. Alar expanse, 12 mm.

The species is very near the other fuscous species of the genus and is easily confused with *Recurvaria cristatella* Chambers, but besides minor colorational variations, it differs in the lack of the hair pencil at the base of the hind wings in the male.

THE LARVA.

In the larva (Pl. II, fig. 5) the usual characters of Gelechiidæ are exhibited. Up to the time of hibernation the young larvæ are light reddish brown, with the head, a plate on the second segment, a small plate on the anal segment, and the upper surface of the legs vandyke brown. Soon after issuing from their hibernacula in the spring they lose the anal plate, and as they reach their full growth many of them turn from brown to pale green, while others exhibit various shades between the two. This color variation of the larva has no effect on the appearance of the moth, for both brown and green larvæ have been isolated and reared, resulting in adults of a uniform type.

The larva shortly after hatching measures a little over 1 mm., or about one-twentieth of an inch, in length. It grows slowly and at the time of hibernation measures from 2.1 to 2.6 mm., and when full grown from 8 to 10 mm., or about three-eighths of an inch, in length.

THE PUPA.

The pupæ (Pl. II, fig. 2) shortly after the transformation takes place vary in color from brown to green, as do the larvæ; in a few days, however, they all turn brown. They measure 4 or 5 mm., or three-sixteenths of an inch, in length.

LIFE HISTORY AND HABITS.

ADULT STAGE.

The first moths (Pl. II, fig. 6) issued in rearing cages at Benton Harbor, Mich., on June 22. Some individuals may have emerged in the orchards before this date, for they were found there in considerable numbers on June 23. In the rearing cages the maximum emergence took place on June 30, and the last moths to appear issued on July 10; the period of emergence thus covered 19 days. In Table I

is given the record of the emerging moths in cages in the rearing shelter and the emergence of hymenopterous parasites of the larvæ. The total number of adults that issued was 383; of larval parasites, 14.

TABLE I.—*Record of emergence of adults and larval parasites of the lesser bud-moth in rearing cages at Benton Harbor, Mich., in 1913.*

Date of emergence.	Number of moths.	Number of larval parasites.	Date of emergence.	Number of moths.	Number of larval parasites.
June 22	5	0	July 2	13	0
23	10	0	3	35	0
24	12	2	4	11	0
25	17	4	5	0	0
26	21	6	6	1	0
27	36	2	7	0	0
28	64	0	8	2	0
29	47	0	9	0	0
30	65	0	10	2	0
July 1	42	0	11	0	0

In figure 1 this record of the emergence of the adults is graphically shown.

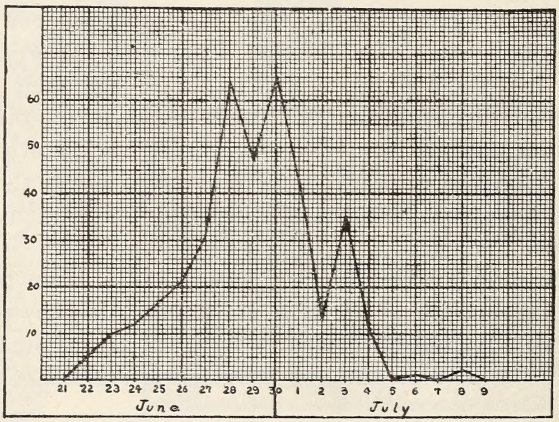


FIG. 1.—Graphic representation of time and relative emergence of adults of the lesser bud-moth in rearing cages at Benton Harbor, Mich. (Original.)

During the first few days of emergence the number of males issuing was greatly in excess of the females; toward the last of the period, however, the reverse was true. Table II shows the proportion of males and females as they issued on successive days.

TABLE II.—*Relative number of males and females of the lesser bud moth issuing in rearing cages at Benton Harbor, Mich., in 1913.*

Date.	Number of males.	Number of females.	Date.	Number of males.	Number of females.
June 24	20	4	June 30	7	15
25	12	3	July 1	3	4
26	10	4	2	6	13
27	12	14			
28	16	17	Total	97	103
29	11	29			

In the field the moths were found in large numbers resting on the trunks of the trees. They remained motionless until touched, and even then often flew only a short distance, taking a new position on the same trunk. As many as 15 were counted on the shady side of the trunk of a small Kieffer pear tree. However, the insects did not confine themselves to the trunks of the trees alone, but were occasionally found resting upon near-by weeds or upon the branches and, in a few cases, upon the leaves.

All attempts to feed the moths in captivity failed. They apparently refused to taste the brown-sugar sirup offered them. Nor were attempts to obtain eggs in confinement more successful, as the insects would not oviposit under the unnatural conditions of the rearing cage.

EGG STAGE.

Although a most diligent search was made for the eggs of the lesser bud-moth, no trace was found of them. This failure is in a measure due to the fact that nothing of the habits of the insects was at that time known to us. The adults were seldom observed anywhere except at rest on the tree trunks, although without doubt they deposit their eggs on the underside of the leaves singly, as evidenced by the location of the entrance opening to the leaf mines. Eggs in the egg tubes of the females were observed when dissected, but nothing of their appearance after oviposition could be surmised.[1]

LARVAL STAGE.

It is in the larval stage that *Recurvaria nanella* spends most of its life. In Benton Harbor the eggs commenced hatching about July 15. The larvæ at this time are very small, measuring scarcely more than 1 mm. in length. They at once bore through the epidermis of the leaf on the underside and commence the construction of a most curiously shaped mine in the inner tissues of the leaf. (See Pl. II, fig. 1.)

The larva first eats its way in a small circle, then constructs a main burrow which soon divides, the branches in turn again dividing, often after the manner of the branching of a tree. The form of these mines, however, is by no means regular, but shows considerable diversity. The insect does not finish the construction of any branch of the mine at once, but feeds at will in all parts, keeping the whole

[1] As this paper is going to press, specimens of eggs of the lesser bud-moth have been received from Mr. E. H. Siegler, of the Bureau of Entomology, who has been successful in obtaining them from moths confined in glass jars, at Benton Harbor, Mich. Some of the eggs received had been loosely deposited among the hairs on the underside of an apple leaf, singly or several sticking together, for the most part along the veins of the leaf. Another lot had been deposited on a twig under the edge of a small scale. The egg is oblong, inclined to be cylindrical, though irregularly so, and is flattened where it comes in contact with another in the cluster. It is minute in size, measuring about 0.32 mm. long by 0.2 mm. broad, and is pale, shining yellow in color.

mine open and ejecting all excrement at the point of entrance. Thus, if the larva, which can be seen through the epidermis, be disturbed, it will rapidly crawl to another part of the mine; and if followed, will escape at the entrance hole.

The larvæ show no preference as to the point of entrance, eating their way into the leaf tissues at any point from the midrib to the edge.

One or many mines may be constructed in a single leaf, according to the degree of infestation. Where the insects are numerous, the mines form a network covering the leaf. It is evident that the adult female in depositing her eggs lays a number at one time on adjacent leaves, as the mines usually appear in groups, several affected leaves occurring on the same twig or neighboring twigs.

Upon the arrival of the first cold days of fall the larvæ begin leaving the mines to construct the small silken hibernacula in which they pass the winter. The desertion of the leaf mines commenced about September 12 (1913), the temperature showing the first considerable drop of the season at that time. By September 17 practically all the larvæ had disappeared from the mines. However, upon picking off small pieces of loosened bark, or lifting up old bud scales, the larvæ were discovered spinning the minute cocoons which were to be their winter shelter.

No preference was shown in the selection of a place for hibernation, the larvæ taking possession of the first available protection. On large trees they confine themselves to the twigs and smaller branches, but on small trees they may be found in abundance on the larger limbs and trunk. The hibernating larvæ on large trees, even where the infestation is severe, are difficult of location, being very small and inconspicuous. However, after a few warm days in the spring the larvæ begin to appear in great numbers, as if spontaneously.

As the weather warms and the buds on the fruit trees swell, one may discover, upon close observation, minute masses of reddish or greenish pellets upon the buds. This is the excrement which the larva within has deposited at the entrance to its burrow (Pl. II, figs. 3 and 4).

The first larvæ at Benton Harbor were observed working in the buds in considerable numbers on April 15, when the buds were just beginning to swell. They probably began emerging in small numbers one or two days before.

The insect appears to show little preference as to the point of its attack on the bud, for it enters either at the side or at the tip. As a rule those entering at the side do so just at the edge of the bud scales, although sometimes one will pierce the scales themselves. In

a few cases larvæ were noted entering buds which had not begun to swell, but which were still in a dormant state. Over the entrance to the burrow the caterpillar spins a fine netlike web. The larva burrows to the center of the bud both by means of eating its way, the material passing through its alimentary canal, and by biting off bits and carrying them to the outside. The latter method is used when the insect is piercing the tough outer layers of the bud.

Should the temperature drop after a warm day has tempted the caterpillars to come out of hibernation, but before they have had the opportunity to enter a bud, they will seek shelter under loose bark on the limbs. Many larvæ were found under the bark on April 16, but by April 23 all had apparently entered buds.

As before mentioned, the larva upon entering a bud makes its way directly to the center, there feasting on the tender ovary of the unopened flower, provided the insect has entered a flower bud, which the majority do. It is this habit which does the greatest amount of injury (Pl. I, fig. 1), for often every bud on a large limb will be affected. After consuming the inner portions the larvæ feed upon the leafy tissue of the bud, remaining within until the bud expands and the leaves begin to unfold.

As the first leaves open out, the larva fastens them together, spinning its fine strand of silk as it crawls about (Pl. I, fig. 2). It now constructs for itself a shelter or cocoon of silk, often rolling over the edge of a leaf and constructing it from within, or bringing the tips of several leaves together and spinning it in the midst, or making a combination of the two methods. As a rule, the larvæ during the day are to be found at rest within this cocoon, giving evidence for the supposition that the insects are nocturnal feeders.

On May 15 it was noticed that some of the nests in the leaves were empty, and by the next day a large percentage of the larvæ had disappeared. However, a search revealed the caterpillars under bits of loose bark on the limbs and trunk constructing cocoons in which to pupate (Pl. II, fig 5). On large trees where there is a great deal of roughened bark the cocoons are difficult to locate, but on smaller trees they will be found clustered in the crevices on the trunk; this is especially true on young pear trees, where most of the bark is smooth, affording the insects no shelter. A search among the leaves and débris on the ground beneath the trees revealed a few larvæ transforming in the shelter there afforded.

The last crawling larvæ in the orchard were found on June 19. Thus the larval stage covers an average period of about 10 months.

The number of molts of the larva was not accurately determined, the only data taken on this subject being measurements of the width of the head taken at successive intervals during the development of

this stage of the insect. These measurements, arranged numerically, are given in Table III. It is not the writers' opinion that these figures show definitely the number of molts, but they are presented merely for what they are worth. However, a study of Table III seems to warrant the interpretation that there are five instars, or four larval molts. In the last instar considerable variation in the width of the head will be noticed, but as this same variation is found among full-grown larvæ taken from their cocoons, they are all considered as belonging to the same stage.

TABLE III.—*Measurements of width of head of larvæ of the lesser bud-moth taken at intervals throughout their development at Benton Harbor, Mich., in 1913.*

Date.	Width of head.	Stage.	Date.	Width of head.	Stage.
	Mm.			Third molt.	
July 29 (just hatched)	0.12			*Mm.*	
	.12			0.31	
	.12			.31	
	.14			.34	
	.15		April 8 (in hibernation)	.35	
	.15			.36	
	.16			.36	
	.16	First instar.		.38	Fourth instar.
	.16			.38	
	.16		April 18 (in buds)	.38	
August	.16			.41	
	.16			.41	
	.16			.43	
	.16			.43	
	First molt.			.48	
				Fourth molt.	
	.19			.56	
	.19			.57	
	.19			.57	
	.19	Second instar.		.59	
	.20			.60	
	.21			.62	
	.21			.62	
	.21			.64	
	.21			.64	Fifth instar.
	Second molt.			.64	
				.66	
	.245			.86	
	.245			.96	
	.25			1.12	
September	.26	Third instar.		.60	
	.275		May 27 (in cocoon)	.64	
	.275			1.02	

PUPAL STAGE.

The first pupæ (Pl. II, fig. 2) of the lesser bud-moth were found on May 18 under the loose bark on the trunks of young peach trees, incased in their small, white, silken cocoons. The last larvæ to pupate in the rearing cages did so on June 16. The average time spent as a pupa is about 19 days, varying, however, from 15 to 30 days.

Table IV is a record kept of isolated larvæ, giving dates of pupation and of emergence as adults.

TABLE IV.—*Pupation and emergence record of the lesser bud-moth in rearing cages at Benton Harbor, Mich., in 1913, showing number of days spent as pupæ.*

No. of observation.	Date of—		Days.	No. of observation.	Date of—		Days.
	Pupation.	Emergence.			Pupation.	Emergence.	
1	June 2	June 25	23	19	June 12	June 30	18
2	June 3	June 27	24	20	June 14	...do....	16
3	...do....	...do....	24	21	...do....	...do....	16
4	...do....	July 3	30	22	...do....	...do....	16
5	June 6	June 27	21	23	...do....	...do....	16
6	...do....	...do....	21	24	...do....	July 1	17
7	...do....	...do....	21	25	...do....	July 3	19
8	...do....	...do....	21	26	June 16	July 1	15
9	...do....	...do....	21	27	...do....	...do....	15
10	...do....	June 28	22	28	...do....	...do....	15
11	...do....	...do....	22	29	...do....	July 2	16
12	June 9	June 27	18	30	...do....	...do....	16
13	...do....	June 26	17	31	...do....	July 3	17
14	...do....	June 28	19				
15	June 10	...do....	18	Average			18.9
16	...do....	...do....	18	Maximum			30
17	...do....	...do....	18	Minimum			15
18	June 12	June 30	18				

INSECT ENEMIES.

The following hymenopterous parasites, representing six families and seven genera, were reared from *Recurvaria nanella*, from material collected in the larval and pupal stages, and confined in breeding jars. Braconidæ: *Phanerotoma recurvariæ* Cushman; Ichneumonidæ: *Diadegma* sp. and *Itoplectis* sp.; Pteromalidæ: A broken, undetermined specimen; Encyrtidæ: *Eupelmus* sp.; Eurytomidæ: *Eurytoma* sp.; Chalcididæ: *Dibrachys* sp.

EXPERIMENTS IN CONTROL.

EXPERIMENT I.—A young apple orchard at Benton Harbor, Mich., was used for experimental spraying against the lesser bud-moth. This orchard consisted of 50 trees of the Oldenburg (*Duchess*) variety about 9 years old. Early in the spring, before the buds began to swell, the trees were examined and numerous hibernating larvæ were found under the loose bark, the infestation appearing uniform over the entire orchard. The orchard was divided into eight plats, each plat consisting of not less than eight trees. The material was applied with a hand barrel sprayer equipped with Vermorel nozzles. The results were determined by actual count of all infested and uninfested fruit and leaf buds from five trees of each plat, 10 days after the blossoming period. The results are shown in Table V.

TABLE V.—*Spraying experiments against the lesser bud-moth on apple, Benton Harbor, Mich., 1913.*

Plat No.	Treatment.	Number of buds infested.	Number of buds sound.	Total number of buds.	Total percentage of sound buds.
I	One application of commercial lime-sulphur solution (1 gal. to 8 gals. of water) on Apr. 8. Trees dormant	1,638	7,534	9,172	82.14
II	One application of soda-sulphur solution (1 lb. to 5 gals. of water) on Apr. 8. Trees dormant	680	4,228	4,908	86.14
III	One application of unfiltered lime-sulphur solution (1 gal. to 8 gals. of water) on Apr. 8. Trees dormant	924	5,918	6,842	86.49
[1] IV	Two applications of arsenate of lead (2 lbs. to 50 gals. of water) on Apr. 16, when buds began to swell, and on May 1, when cluster buds opened	956	7,019	7,975	88.01
[1] V	Three applications of arsenate of lead (2 lbs. to 50 gals. of water) on Apr. 16, when buds began to swell, on Apr. 24, when cluster buds were half open, and on May 1, when cluster buds were open.	523	8,006	8,529	93.86
VI	Check (unsprayed)	4,949	4,129	9,078	45.48

[1] Lime-sulphur solution, 1½ gallons to 50 gallons of spray, was added in the last application in plats IV and V, mainly for the control of apple scab.

As will be noted, the best results were obtained on Plat V, where three applications of arsenate of lead were used. In this case the buds were kept covered with poison, so that the larvæ had little chance to gain entrance into them. The next best results were obtained where two applications of arsenate of lead were used. However, the application of the lime-sulphur and the soda-sulphur solutions when the trees were dormant, both used at the strength recommended for the San Jose scale, were almost as effective as the arsenate of lead. The action of the sulphur compounds on the larvæ is not known, but they probably act largely as repellents.[1] The larvæ were examined in their hibernacula at various intervals from the time the application was made until they came out to enter the buds, and in all cases they were found unhurt and untouched by the spray. However, this was expected, since their hibernacula were protected from the spray by the loose bark under which they were hidden. Then, too, the hibernacular cases are of such construction that they can not be easily penetrated by spray. When the larvæ emerged, they disappeared, either having been repelled from the tree or killed by the action of the sulphur sprays subsequent to their emergence.

Almost the entire crop of fruit on the check trees was lost on account of the work of the larvæ, there being less than half a dozen apples on each tree, while the crop was unhurt on the sprayed trees.

EXPERIMENT II.—An apple orchard of the Rhode Island Greening variety, consisting of 120 trees about 40 years old, belonging to Mr. W. H. Woodruff, Benton Harbor, Mich., was also used for ex-

[1] Lime-sulphur solution was found to act as a strong repellent against certain other lepidopterous larvæ in other experiments conducted during the season.

perimental spraying against the lesser bud moth in 1913. Previous to that year the orchard had been badly neglected, not having been cultivated, pruned, or thoroughly sprayed for several years. The owner reported that no crop had been harvested from the orchard during the preceding eight years, although it is not known that this was due to the work of the lesser bud moth. However, last season it was noted by the senior author that almost every bud was infested with this insect, resulting in a total loss of the crop. The experimental spraying was done with a gasoline-power sprayer equipped with nozzles of the Vermorel type. The orchard was divided into six plats, each containing not less than 14 trees. The treatments and dates of application are shown in Table VI.

TABLE VI.—*Treatments and dates of applications of sprays for the lesser bud-moth, Mr. W. H. Woodruff's apple orchard, Benton Harbor, Mich, 1913.*

Plat No.	Treatment at—		
	First application, Apr. 7. (Trees dormant.)	Second application, Apr. 12. (Buds swelling.)	Third application, Apr. 29. (Cluster buds open.)
I	Lime-sulphur solution (1 : 8)..	None.....	None.
II	Lime-sulphur solution (1 : 8)..	None.....	Lime-sulphur solution (1½ : 50).
III	Soluble-oil solution (1 : 15).....	None.....	Do.
IV	Blackleaf 40.....	None.....	Do.
V	None.....	Arsenate of lead (2 : 50).....	Lime-sulphur solution (1 : 50) and arsenate of lead (2 : 50).
VI	Check (unsprayed).....	.....	

As the trees in this orchard were too large for counts to be made of the infested and uninfested buds, the results were determined only by observation and by comparing the amount of the fruit that set on the sprayed and unsprayed trees. While the infestation was not as heavy in this orchard this year as last, the larvæ were numerous enough materially to affect the crop, and at the time of blossoming quite a contrast could be noted between certain sprayed plats and the unsprayed plat.

Entirely satisfactory results were obtained on Plat I, which received only an application of lime-sulphur solution at the rate of 1 gallon to 8 gallons of water when the trees were in the dormant state. Only a few larvæ could be found on these trees at blossoming time, and there was practically no loss of fruit from their work, the trees bearing a good crop. Plat II received the same treatment, with the exception of an additional application of lime-sulphur solution at the rate of 1½ gallons to 50 gallons of water when the cluster buds opened. The results were the same as on Plat I. Plat III, sprayed in the dormant state with soluble oil at the rate of 1 gallon of the oil to 15 gallons of water, and Plat IV, receiving a dormant application of blackleaf 40 at the rate of 1 gallon of this insecticide to 800 gallons of water, gave no noticeable results. Both of these plats re-

ceived an application of lime-sulphur solution at the rate of 1½ gallons to 50 gallons of water when the cluster buds opened, chiefly for the purpose of controlling apple scab. Plat V received two applications of arsenate of lead at the rate of 2 pounds to 50 gallons of water when the buds were swelling and when the cluster buds opened. The results on this plat were satisfactory, being practically the same as where the dormant application of lime-sulphur solution was used.

More than 50 per cent of the fruit buds on the unsprayed trees were infested with the larvæ, and the trees set less than half a crop of fruit.

Observations were made throughout the vicinity of Benton Harbor, Mich., to determine the extent of infestation of the lesser bud moth. It was noted that practically all unsprayed apple and peach orchards were badly infested, while all apple orchards which were thoroughly sprayed for the San Jose scale in the dormant state and followed up by later sprayings were free from infestation. No apple orchards were found which received only the dormant application, so that the effect of this one spraying could not be determined. However, the peach orchards in this section are sprayed with lime-sulphur late in the spring, just before the buds open, for control of the San Jose scale and leaf-curl, and in only a few cases do they receive any other application of spray. In these orchards, which receive only the dormant application of the lime-sulphur solution, the lesser bud-moth is thoroughly controlled, while unsprayed peach orchards are moderately to badly infested.

RECOMMENDATIONS FOR CONTROL.

The foregoing experiments, as well as general observations made throughout the infested section at Benton Harbor, Mich., show that the lesser bud-moth can be controlled by thoroughly spraying the trees in the dormant state with lime-sulphur solution at 32° Baumé used at the rate of 1 gallon to 8 gallons of water. Lower testing material should be used at increased strengths. The spraying should be done just before the buds swell, or preferably when the buds are swelling. This treatment is especially to be recommended, as it involves no extra application where it is necessary to spray during the dormant season for other insects, such as the San Jose scale, oyster-shell scale, scurfy scale, and blister-mite, and for the peach leaf-curl.

In cases where it is not expedient to use the lime-sulphur solution two early applications of arsenate of lead at the rate of 2 pounds to 50 gallons of water should be made. This should be applied first when the buds are swelling and again when the cluster buds open. This latter application coincides with the first apple-scab treatment. In

case of a bad infestation it would be advisable to make another application of arsenate of lead when the buds are half open or bursting. It should be borne in mind that thorough control of this insect by use of an arsenical necessitates keeping the buds covered with poison as nearly as possible from the time they begin to swell until they are open.

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